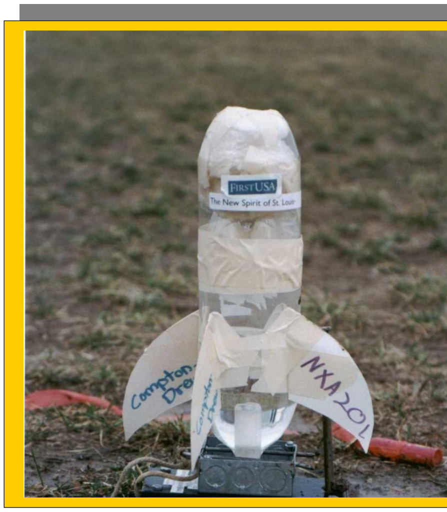
Dynamic Design: Launch and Propulsion

Investigating Water Rockets

TEACHER GUIDE

BACKGROUND INFORMATION



This session deals with two important issues that will be addressed throughout the Launch and Propulsion unit. The first and most important issue is safety. Water bottle rocketry is fun and it can be a great vehicle for understanding many scientific concepts; however, all safety precautions must be followed.

During this session, students will get a complete overview of the safety issues involved with building and launching bottle rockets. Safety is a major issue. Be certain that you study the accompanying "Safety Rules" with your students and monitor strict safety regulations during all launches. Use the safety checklist each time you build or launch. Specific information is included in this unit. Students will build an altitude tracker and practice using it preparation for the upcoming rocket launches.

The altitude tracker makes use of simple trigonometry to determine the altitude a rocket reaches in flight. For most accurate readings, at least four altitude readings should be taken. These reading stations should be at a distance of 10 meters from the launch pad at each position including north, east, south, and west. Once a rocket is launched, the four student spotters (standing at reading stations) should follow the path of the rocket through the altitude tracker sighting tube. When the rocket reaches it's highest point (apex), each spotter should hold the weighted string in position that it naturally falls and read and record the angle. Once the four angles are gathered, the high and the low angles should be omitted. The two remaining angles should be averaged. Students should then find the angle on the conversion chart, identifying the height that the rocket reached.

Students will work in the same collaborative (design) groups for "What do I need to know before launch?" as they did for the other parts of the module. This will allow you to observe and experience what they know and what they don't know about rocketry, and provide the motivation to learn more. Students work in design groups to discuss the first attempt at launching rockets; they will also assign expert roles. In expert groups, students will gain specific knowledge about one of the variables of successful rocket launching. They will bring this information back to their design group and that group will put together a newly designed rocket. After additional testing, they will launch in the competition to find who can launch a water rocket the highest.

The teacher's guide in this section is divided into information for teachers to interact with specific expert groups. The teacher's role becomes that of a facilitator of learning rather than the source of knowledge. With your supervision, the students can complete the activities within the expert learning group sessions. Encourage them to ask questions and find answers for themselves through the process. Your close supervision is required during the test launches. We recommend that you schedule test launches on one specific day of the week or when a critical mass is ready to test their variable. You may want to recruit the assistance of another adult to assist in this process.

Once students have completed their expert group work, they will compare launch windows of Genesis and other missions. Students explore the safe parameters (weather conditions etc.) that are guidelines used to determine if a launch can happen. Students use a simple fault tree analysis to make decisions regarding a launch. This will include using technology to monitor the conditions at the local site for launch to determine if launch should happen.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8

Science As Inquiry

Abilities Necessary to do scientific inquiry

Physical Science

Motion and Forces

Science and Technology

Abilities of technological design

Understandings about science and technology

Science in Personal and Social Perspectives

Personal health

Grades 9-12

Science As Inquiry

Abilities Necessary to do scientific inquiry

Physical Science

Motion and Forces

Science and Technology

Abilities of technological design

Understandings about science and technology

Science in Personal and Social Perspectives

Personal and community health

(View a full text of the National Science Education Standards.)

PRINCIPLES AND STANDARDS FOR SCHOOL MATHEMATICS ADDRESSED

Measurement Standard for Grades 6-8

Understand measurable attributes of objects and the units, systems, and processes of measurement

Understand both metric and customary systems of measurement

Apply appropriate techniques, tools, and formulas to determine measurements

Select and apply techniques and tools to accurately find length and angle measures to appropriate levels of precision

Problem Solving Standard for Grades 6-8

Solve problems that arise in mathematics and in other contexts

Measurement Standard for Grades 9-12

Understand measurable attributes of objects and the units, systems, and processes of measurement

Make decisions about units and scales that are appropriate for problem situations involving measurement

Problem Solving for Grades 9-12

Solve problems that arise in mathematics and in other contexts

(View a full text of the Principles and Standards for School Mathematics.)

NATIONAL EDUCATIONAL TECHNOLOGY STANDARDS ADDRESSED

Technology Standards for Students K-12

Technology productivity tools

Students use technology tools to enhance learning, increase productivity and promote creativity.

Technology research tools

Students use technology to locate, evaluate, and collect information from a variety of sources.

Technology problem-solving and decision-making tools
Students use technology resources for solving problems and making informed decisions.

Technology Standards for Students 6-8
Use content specific tools, software and simulations to support learning and research

Collaborate with peers, experts, and others using telecommunications and collaborative tools to investigate curriculum-related problems, issues, and information, and to develop solutions or products or audiences inside and outside the classroom

(View a full text of the National Education Technology Standards

MATERIALS

What do I need to know before launch?
- Appendix A, "Safety Rules"
- Appendix B, "Safety Checklist"
- Student Activity, "Measuring Altitude"
- Altitude tracker pattern (this can be copied or glued onto tag board)
- Thread, lightweight string, or fishing line
- Cellophane tape
- Small washer or 1-2 ounce fishing sinker
- Scissors
- Rope or string to measure out range (10 meters)
- Angle-to-height conversion chart
- Tennis ball per pair of students

Nosecone Experts
- Student Activity, "What a Drag"
- Paper towel tube
- Appendix C, "Nosecone Patterns"
- Meter stick
- Several 2-liter plastic soft drink bottles
- Modeling clay
- Card stock
- Leaf blower or vacuum set to blow
- Books to make a path
- Long hall or open area

Fin Experts (two groups)
- Student Activity, "Flying Straight" for students in both groups
- Student Activity, "Investigating Fin Shape or Size" for one group
- Student Activity, "Investigating Fin Number and Placement" for the second group
- Paper towel tubes
- Tag board (for fins)
- Metric ruler
- Cellophane tape and/or glue
- Scissors
- Safety glasses
- Launching mechanism (vacuum with blower or leaf blower)
- Meter stick for measuring distances
- Arrows with feathers and without feathers

Propulsion Experts

- Student Activity, "Fly Like an Eagle"
- Student Activity, "Altitude vs. Water Volume"
- Student Activity, "Altitude vs. Water Pressure"
- Several 2-liter plastic soft drink bottles
- Water
- Graduated cylinders (one liter)
- Launcher http://www.nerdsinc.com/rock_prod.html
- Tire pump or air compressor
- Safety glasses
- Altitude trackers
- Conversion charts
- Rope to measure out range (10 meters)
- Compass to determine north, south, east, west

Weather or Not

- Copy of the Student Activity, "Weather or Not"
- Access to a computer with the Internet
- Weather instruments for measuring wind speed, direction, visibility, and temperature

PROCEDURE

What do I need to know before launch?

1. Read through all "Safety Rules" with students and refer to the "Safety Checklist." Students should sign the safety rules. If you have already discussed the safety rules with students, ask them to point out the safety issues to you as they read through the directions for "Constructing an Altitude Tracker" and "Measuring Altitude."

2. Have each student construct an altitude tracker.

3. Have students complete the Student Activity, "Measuring Altitude" in their design groups.

4. Using a jigsaw method, divide your design groups into four expert groups. These include:
   a. Nosecone
   b. Fin numbers and placement
   c. Fin size and shape
   d. Propulsion

Once the expert groups have been assembled, provide Student Activity sheets and instructions to the four groups.

> **Alternate Strategy Tip**
>
> Refer to the Teacher Guide "You Get What You Pay For" to include an economics component for the Interaction and the Assessment sections.

The Nosecone Experts

Description:
Students working in this expert group will experiment with different nosecone shapes to determine the advantages and disadvantages of each type. Conic, parabolic, and flat shapes will be tested to determine which is most aerodynamic. Students will also need to consider the recovery system that will be used, as this will be placed inside the nosecone.

Background:
Aerodynamics is the branch of science that deals with the motion of air and the forces on bodies moving through the air. There are four forces that act on a rocket. They are lift, drag, weight, and thrust. For a graphic illustration of these forces, go to http://www.grc.nasa.gov/WWW/K-12/airplane/rktfor.html.

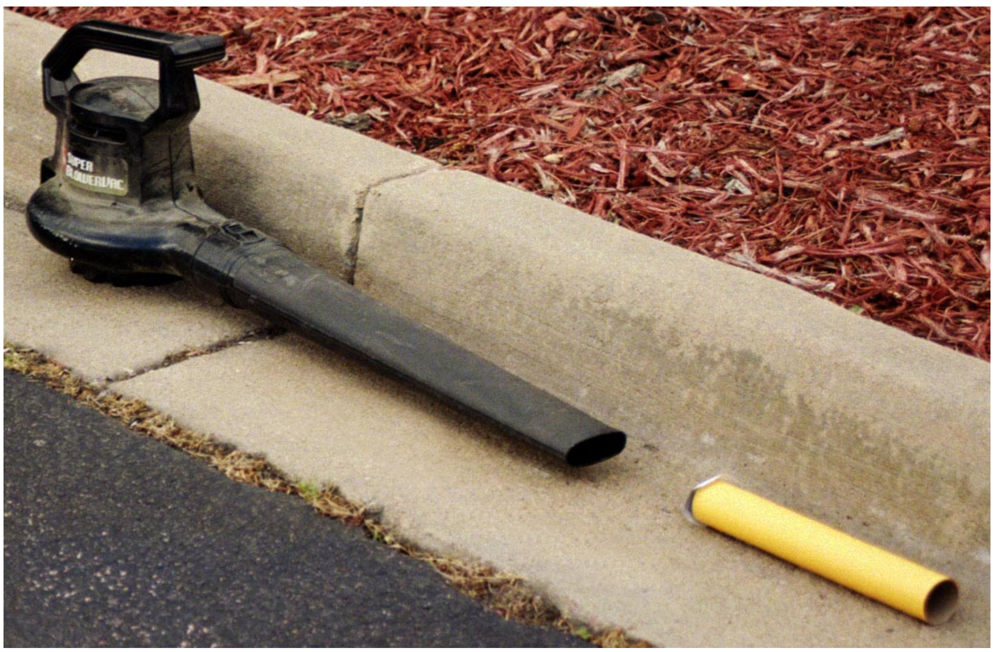
Drag is a force that opposes the upward movement of the rocket. It is generated by every part of the rocket. Drag is a sort of aerodynamic friction between the surface of the rocket and the air. Factors that affect drag include the size and shape of the rocket, the velocity and the inclination of flow, and the mass, viscosity and compressibility of the air. For an interesting computer simulation where you can manipulate an airfoil's thickness, the air speed, altitude, and angle, go to http://www.grc.nasa.gov/WWW/k-12/FoilSim/index.html. There are also teacher lesson plans here to use the simulation in class.

Procedure:

1. Students in this expert group will complete the pre-lab sheet "What a Drag" to allow them to build on their past experiences with aerodynamics.

2. Students construct nosecones by cutting out three different nosecone shapes from card stock. They will then attach the nosecones onto paper towel tubes. This time modeling clay can be used inside the nosecone to provide mass.

3. Use a commercial leaf blower or a vacuum cleaner with its airflow reversed to "blow" to force the rocket backwards. This should be done on a narrow track to keep the rocket in line with the wind. (books may be lined up to make this track)



4. Students should measure the distance the rocket traveled backwards. Record the results and complete the nosecone expert report on the "What a Drag" sheets. When students have completed the expert group work, instruct them to begin the copy of the Student Activity, "Weather or Not."

The Fin Experts

Description:
Students working in these expert groups will examine the variables related to fins. One group will investigate shape and size, while the other will explore fin number and placement. Students may investigate various fin shapes including rectangle, triangle, semicircle, or polygon each in various sizes. Students may investigate three, four, or six fins placed in an even or uneven pattern. The goal for the fin experts is to gather evidence on the best fin design to allow the rocket to be stable during flight, based on research and observations, and then share their collective findings with their own design team.

Background Information:
A rocket with no fins is much more difficult to control than a rocket with fins. The size and shape of the fins, as well as their number and placement, is critical to achieve adequate stability while not adding too much weight. For more information on stability and control systems, see NASA's *Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology* (pages 21-24).

Teaching Tip

You may want to further divide the fin shape and size group into two groups. One group should investigate shape, the other should investigate size.

Procedure:
1. Have students complete the Student Activity “Flying Straight.” They will probably want to know:
   - Does fin shape make a difference?
   - Does fin size make a difference?
   - Would more fins work better?

2. Students capable of designing their own investigation should complete “Flying Straight,” numbers 12-15.

3. Students who need more structure should complete the Student Activity “Investigating Fin Shape or Size” or “Investigating Fin Number and Placement.” Distribute the “Investigating Fin Shape or Size” activity and instruct one group to complete the investigations on this sheet. Distribute the Student Activity “Investigating Fin Number and Placement” to the other group.

4. When the groups have completed the investigations, look at their plans. It is important that students examine at least these three separate variables: fin shape, fin size, and fin number/placement. Some students may be ready to conduct their own experiments; other students may require more structure.

5. Time should be provided for students to discuss their results and conclusions.

6. Individual students should write a one-page paper summarizing what they have learned through their research and observations about the aerodynamics of fins. They need to make their explanation clear enough so that other people in their expert group can understand it. Have students exchange papers and complete a short peer review.

7. Each of the two groups that investigated fins should write a group paper summarizing their findings based on evidence gathered during their research and observations. That summary should be shared with other members of design team. When students have completed the expert group work, instruct them to begin the copy of the Student Activity “Weather or Not.”

The Propulsion Experts

Description:
Students working in this expert group will determine the best water volume and the best launch pressure to make a naked 2-liter bottle go the specified height (20 meters). The goal of the propulsion experts is to gather evidence regarding optimum pressure and water volume, based on research and observations, and then share their collective findings with their own design group.

Background Information:
A water bottle rocket is a 2-liter soda bottle filled with compressed air and water. During launch, when the pump valve is opened, the compressed air and water are released, sending the rocket in an upward direction. Students will have the opportunity to experience Newton's Three Laws of Motion as well as expand their conceptual understanding of motion, force, mass, and momentum.

For a detailed explanation of how these Three Laws of Motion apply to water bottle rockets, see the Student Text “Newton’s Laws of Motion and Rockets.”

Procedure:
1. Have students complete the Student Activity “Fly Like an Eagle.” They will probably want to know:
   - What volume of water works best?

- Will it fly without water?
- If a little water works, will a lot work better?
- Will it fly best when it is totally full?
- Does the launch pressure matter?

2. Look at their plans. It is important that students in this expert group examine at least these two variables: volume of water and launch pressure. Some students may be ready to conduct their own experiments other students may require more structure. Student Activities, “Altitude vs. Water Volume” and “Altitude vs. Water Pressure” are available to use as a guide. Once students have tested the variables (volume of water and launch pressure) independently, they may wish to look at manipulating other variables. They may also want to look at various volumes of water at various pressures. Watch as they unknowingly transform into research scientists attempting to answer questions that they ask themselves. Listen carefully; many will (in their descriptions) be describing Newton's Laws of Motion. At just the right teachable moment, these laws can be explained and made understandable to very young students. Typical student statements that set the stage for new understandings include:
   - Why did the rocket that was full of water barely take off? "It was too heavy (massive)." (Newton's First Law)
   - The rocket didn't have enough "oomph " (force) to make it take off. Why? There was not enough force for the relatively huge mass. (Newton's Second Law)
   - The water went one way and the rocket went the other way." (Newton's Third Law)

3. Questions that might be asked to get the students thinking in the right direction include:
   - Why did the rocket that was full of water barely take off?
   - What happens to the rocket as the water inside the bottle went down?
   - If you could eject the water twice as fast from the rocket, what effect would this have on the rocket?

4. At the end of the lesson, ask each student to write a one-page paper, using their own words, describing what makes the bottle rockets fly. They need to make their explanation clear enough so that other people in their expert group can understand it. Have students exchange papers and complete a short peer review.

5. Then ask students to write a group paper, to share with their design group, to best explain why rockets fly. When students have completed the expert group work, instruct them to begin the copy of the Student Activity “Weather or Not.”

Weather or Not

1. Distribute the copy of the Student Activity “Weather or Not.” Instruct students to read the background information and to work in their design groups to develop weather criteria for determining if a launch should take place. Circulate around the room offering assistance for groups that might need it.

2. Using a computer hooked up to a projector, display the current conditions at your school using http://www.weather.com/ or another source. Record the current conditions on the board and determine as a class if a launch could occur today.

3. Listen to students to determine the best way to come to consensus on the weather conditions necessary to launch a water rocket. Using this method, synthesize the student criteria into a class launch criterion to be used during the competition in the assessment section.

Alternate Strategy Tip

Have weather instruments available for students to take real time weather data and record this in the classroom. This will allow students to read weather instruments and at the same time find weather information at your launch site.

TEACHER RESOURCES

Publications

National Aeronautics and Space Administration. (1996). *Rockets: A Teacher’s Guide with Activities in Science Mathematics, and Technology*. Office of Human Resources and Education. Washington, DC.
On line [Available] at http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Rockets/Rockets.pdf

Web sites

http://members.aol.com/hayhurst1/h2orocket.htm
This is an eighth grade teacher's site with a lot of construction information.

http://nso99rockets.cjb.net/
Pictures of Science Olympiad rocket winners.

http://ourworld.compuserve.com/homepages/pagrosse/h2oRocketIndex.htm
Good detail for all parts of the construction process.

http://perso.wanadoo.fr/alain.juge/English/Fins.htm
Great site for construction advice on fins.

http://perso.wanadoo.fr/alain.juge/English/Recovery.htm
Good recovery information.

http://www.ag.ohio-state.edu/~rockets/
4H Rockets Away website.

http://www.ag.ohio-state.edu/~rockets/cgi-bin/design_zone.cgi
Great simulation for testing variables such as weight, amount of water, etc.

http://www.alphalink.com.au/~brucej/roc.htm
All kinds of construction ideas.

http://www.geocities.com/CapeCanaveral/Lab/5402/
Construction information.

http://www.geocities.com/CapeCanaveral/Lab/5412/
Site for simulations of launches.

http://www.grc.nasa.gov/Other_Groups/K-12/airplane/bgmr.html
NASA's Rocket page. Good for teachers and students.

http://www.grc.nasa.gov/Other_Groups/K-12/freesoftware_page.htm
Simulation for the design of wings and fins.

http://www.nerdsinc.com/
Commercial site for purchasing rocket launchers.

http://www.netspace.net.au/~bradcalv/myrocket.htm
Nice rocket construction ideas.